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XIX. *Observations on the heights of mountains in the north of England.* By Thomas Greatorex, Esq. F. L. S. In a letter to Thomas Young, M. D. For. Sec. R. S.

Read May 7, 1818.

HAVING been desirous, for many years past, to revisit the lakes in the north of England, and wishing, when I should be able to take that tour, to make some experiments on one of the mountains in that district, I applied to the late Mr. RAMSDEN, who made for me the following instruments :

A mountain barometer.

A stationary do. (the mercury of both boiled in the tube.)

A telescope with cross-wires, and a level fitted to it, mounted on a tripod-staff.

And a small theodolite, with compass, &c.

These he assured me were made with the greatest care.

I have this summer passed some weeks in the vicinity of the Lakes ; and at Keswick I fortunately met with one of those superior self-taught geniuses, not uncommon in the North, who entered into all my views, and proved eminently serviceable to me. His name is OTLEY, and he is a watch-maker, but acts occasionally as guide up the mountains, &c.

As I wished to measure Skiddaw geometrically down to the average level of Derwent Water, I had a tapering staff made about 28 feet long, shod with an iron point, and very carefully graduated from an accurate standard yard measure, sent from the proper office, in London.

The graduation commenced from a zero about 3 feet from the bottom of the staff, so that from the zero to its top was exactly 25 feet ; the top ending in a bluntish point.

Twelve feet six inches of the upper part of the staff could occasionally be separated from the lower part, both for the convenience of carrying, and in case the wind should prevent the use of the whole length. Small cords were also attached to it, for the purpose of holding it steady and perpendicular.

We first determined the height of OTLEY's house above the lake, which was 10 yards, and at this height the stationary barometer was placed ; and Mr. CROSTHWAITE, of the Keswick Museum, undertook to note its variation and that of the thermometer every half hour.

We then ascended Skiddaw, accompanied by Mr. AIREY, a black-lead pencil maker (who proved an excellent assistant), and two boys. On the summit the barometer was set up. I first adjusted it, and privately noted down the height of the mercury ; then purposely deranged it, to let OTLEY re-adjust it, and write down his observation, which never differed from mine more than one thousandth of an inch during the whole series of observations. The heights of the attached and detached thermometers being also noted, we proceeded to the measurement by the level and staff.

The telescope being levelled, and its cross wires intersecting the highest point of the mountain, it was then pointed in the direction of the most convenient descent, and the staff carried down the hill till its top exactly coincided with the cross wires, the level of the telescope being carefully preserved ; the perpendicularity of the staff was ascertained by

plumb lines. And here I must mention how greatly we were favoured by the weather: the sun only shone during the first observation, and it was nearly a calm during the whole of the measurement, so that AIREY could frequently, by inserting the pole a little in the ground, set it on a balance, which would remain during the time necessary for adjusting the level, and observing it.

I have also to observe, that we chose so precipitous a descent, that the pole was seldom 40 feet from the telescope, therefore no allowance was necessary for the earth's curvature.

I found the most expeditious and exact mode of managing the pole, was to stop Mr. AIREY, when I perceived its top to be about an inch above the cross wires; as I could then make signs to him to press it into the earth by little and little till the coincidence was exact: the telescope was then carried down to the pole, and placed (when levelled) in exact correspondence with the zero. The pole was again removed down to a new station, and this mode continued till we had compleated six observations, or 50 yards of descent. Here the barometer was again set up, separately examined as before; and this process continued to the foot of the mountain.

After descending 175 yards, it was necessary to take a dead level of half a mile, which was corrected by several observations back and forward, as also by a middle station.

We measured 400 yards down the first day, and on the following day compleated 900 yards, which brought us to the village of Appleshwaite, and near the level of Bristow Hill, about a mile distant.

The next day many observations were made back and

forward between Armathwaite and Bristow Hill, allowing 8 inches for the earth's curvature : a small allowance appeared necessary for refraction, the object appearing rather lower than it ought to have been. (This was in the forenoon.)

From Bristow Hill, by means of a middle station, a level was taken to Crow Park, close to the lake, and the measurement completed down to the mean height of Derwent Water.

Results of the levelling.

| | yds. | ft. | in. |
|---|------|-----|-----|
| From the summit of Skiddaw to Applethwaite | 900 | 0 | 0 |
| Down to the level of Bristow Hill | 5 | 0 | 7½ |
| Thence to the level of Crow Park | 14 | 2 | 5 |
| Down to the average height of Derwent Water | 16 | 0 | 3 |
| <hr/> | | | |
| Skiddaw above the lake | 936 | 0 | 3½ |
| Derwent Water above the sea at low-water mark, according to an accurate measurement by the late Mr. CROSTHWAITE | 76 | 0 | 0 |
| <hr/> | | | |
| Height of Skiddaw by levelling | 1012 | 0 | 3½ |

Results of the several barometrical observations on the summit of Skiddaw, Sept. 15th. 1817, at 10 hours 50 min. A. M.

| | | |
|--|---------|-------------------------------------|
| | | inches. |
| Barometer below. 10 yds. above the lake | 30.050. | Ther. 61°. |
| Barometer above | 27.156. | Th. attached 57°. Do. detached 50°. |
| | | yds. |
| Whence, by Dr. MASKELYNE's formula, the height | = | 926.1685 |
| Measured height | = | 926 |
| | | error + .1685 |
| | | <hr/> |
| By Dr. HUTTON's formula | = | 925.285 |
| | | error — .715 |

| | | |
|------------------|---------|----------------------------|
| | | 50 yards down. 12 h. 20 m. |
| Bar. below | 30.030. | Ther. 62°. |
| Do. above | 27.310. | Do. 56°.* |
| | | yds. |
| Measured height | = | 876 |
| By Dr. MASKELYNE | = | 873.194477 |
| | | error — 2.805523 |
| | | <hr/> |
| By Dr. HUTTON | = | error — 3.948 |

* The attached and detached thermometers did not differ for the remainder of the observations.

| | | | | | |
|------------|---|---------------------------|--------------------|---|-----------------|
| | | 100 yards down. 1 h. 10m. | | | |
| | | inches. | | | |
| Bar. below | - | - | 30.010. Ther. 62°. | | |
| Do. above | - | - | - 27.444. Do. 56°. | | yds. |
| | | | Measured height | - | 826 |
| | | | By Dr. MASKELYNE | - | 821.71247 |
| | | By Dr. HUTTON | | - | error — 4.28753 |
| | | | | - | error — 4.6032 |
| | | 150 yards down. 1 h. 55m. | | | |
| | | 30.010. Ther. 63°. | | | |
| Bar. below | - | - | 27.590. Do. 56°. | | yds. |
| Do. above | - | - | Measured height | - | 776 |
| | | | By Dr. MASKELYNE | - | 772.3057 |
| | | By Dr. HUTTON | | - | error — 3.6943 |
| | | | | - | error — 4.6444 |
| | | 200 yards down. 4h. 20m. | | | |
| | | 30. Ther. 61°. | | | |
| Bar. below | - | - | 27.708. Do. 53°. | | yds. |
| Do. above | - | - | Measured height | - | 726. |
| | | | By Dr. MASKELYNE | - | 724.7245 |
| | | By Dr. HUTTON | | - | error — 1.2755 |
| | | | | - | error — 2.092 |
| | | 250 yards down. 4h. 52m. | | | |
| | | 30. Ther. 60°. | | | |
| Bar. below | - | - | 27.851. Do. 50°. | | yds. |
| Do. above | - | - | Measured height | - | 676. |
| | | | By Dr. MASKELYNE | - | 672.252 |
| | | By Dr. HUTTON | | - | error — 3.748 |
| | | | | - | error — 4.3152 |
| | | 300 yards down. 5h. 50m. | | | |
| | | 29.990. Ther. 58°. | | | |
| Bar. below | - | - | 28.002. Do. 48°. | | yds. |
| Do. above | - | - | Measured height | - | 626. |
| | | | By Dr. MASKELYNE | - | 616.731 |
| | | By Dr. HUTTON | | - | error — 9.269 |
| | | | | - | error — 9.6532 |
| | | 350 yards down. 6h. 45m. | | | |
| | | 29.987. Ther. 57°. | | | |
| Bar. below | - | - | 28.150. Do. 47°. | | yds. |
| Do. above | - | - | Measured height | - | 576. |
| | | | By Dr. MASKELYNE | - | 566.3645 |
| | | By Dr. HUTTON | | - | error — 9.6355 |
| | | | | - | error — 9.91 |

| | | | |
|--|---|-----------|--------------------|
| 400 yards down. 7h. 15m. | | | |
| inches. | | | |
| Bar. below | - | - | 29.980. Ther. 55°. |
| Do. above | - | - | 28.310. Do. 47°. |
| | | | Measured height |
| | | | By Dr. MASKELYNE |
| | | yds. | 526. |
| | | | 513.3128 |
| | | error — | 12.6872 |
| | | - error — | 12.84 |
| By Dr. HUTTON | | | |
| 400 yards down. Sept. 6th, 1817. 10h. 15m. A. M. | | | |
| Bar. below | - | - | 29.890. Ther. 59°. |
| Do. above | - | - | 28.240. Do. 54°. |
| | | yds. | 526. |
| | | | Measured height |
| | | | By Dr. MASKELYNE |
| | | | 517.89753 |
| | | error — | 8.10247 |
| | | - error — | 8.674 |
| By Dr. HUTTON | | | |
| 450 yards down. 11h. 5m. | | | |
| Bar. below | - | - | 29.900. Ther. 59°. |
| Do. above | - | - | 28.396. Do. 54°. |
| | | yds. | 476. |
| | | | Measured height |
| | | | By Dr. MASKELYNE |
| | | | 470.2667 |
| | | error — | 5.7333 |
| | | - error — | 6.2514 |
| By Dr. HUTTON | | | |
| 500 yards down. 11h. 54m. | | | |
| Bar. below | - | - | 29.900. Ther. 61°. |
| Do. above | - | - | 28.564. Do. 56°. |
| | | yds. | 426. |
| | | | Measured height |
| | | | By MASKELYNE |
| | | | 417.8833 |
| | | error — | 8.1167 |
| | | - error — | 8.65 |
| By Dr. HUTTON | | | |
| 550 yards down. 12h. 24m. | | | |
| Bar. below | - | - | 29.905. Ther. 61°. |
| Do. above | - | - | 28.730. Do. 56°. |
| | | yds. | 376. |
| | | | Measured height |
| | | | By Dr. MASKELYNE |
| | | | 365.8427 |
| | | error — | 10.1573 |
| | | - error — | 10.6186 |
| By Dr. HUTTON | | | |
| 600 yards down. 12h. 53m. | | | |
| Bar. below | - | - | 29.908. Ther. 61°. |
| Do. above | - | - | 28.866. Do. 56°. |
| | | yds. | 326. |
| | | | Measured height |
| | | | By Dr. MASKELYNE |
| | | | 323.098758 |
| | | error — | 2.901242 |
| | | - error — | 3.326 |
| By Dr. HUTTON | | | |

| | | | | |
|------------|---|--------------------------|--------------------|----------------|
| | | 650 yards down. 2h. 5m. | | |
| | | inches. | | |
| Bar. below | - | - | 29.910. Ther. 60°. | |
| Do. above | - | - | 29.046. Do. 56°. | yds. |
| | | Measured height | - | 276. |
| | | By Dr. MASKELYNE | - | 266.8915 |
| | | | error — | 9.1085 |
| | | By Dr. HUTTON | - | error — 9.446 |
| | | 700 yards down. 2h. 38m. | | |
| | | 29.910. Ther. 60°. | | |
| Bar. below | - | - | 29.188. Do. 56°. | yds. |
| Do. above | - | - | | 226 |
| | | Measured height | - | 221.8442 |
| | | By Dr. MASKELYNE | - | |
| | | | error — | 4.1558 |
| | | By Dr. HUTTON | - | error — 4.446 |
| | | 750 yards down. 3h. 5m. | | |
| | | 29.920. Ther. 59°. | | |
| Bar. below | - | - | 29.364. Do. 57°. | yds. |
| Do. above | - | - | | 176. |
| | | Measured height | - | 171.333 |
| | | By Dr. MASKELYNE | - | |
| | | | error — | 4.667 |
| | | By Dr. HUTTON | - | error — 4.888 |
| | | 800 yards down. 3h. 35m. | | |
| | | 29.930. Ther. 59°. | | |
| Bar. below | - | - | 29.548. Do. 58°. | yds. |
| Do. above | - | - | | 126. |
| | | Measured height | - | 117.82 |
| | | By Dr. MASKELYNE | - | |
| | | | error — | 8.18 |
| | | By Dr. HUTTON | - | error — 8.2996 |
| | | 850 yards down. 4h. 5m. | | |
| | | 29.940. Ther. 58°. | | |
| Bar. below | - | - | 29.716. Do. 58°. | yds. |
| Do. above | - | - | | 76. |
| | | Measured height | - | 69.36818 |
| | | By Dr. MASKELYNE | - | |
| | | | error — | 6.63182 |
| | | By Dr. HUTTON | - | error — 6.4918 |
| | | 900 yards down. 4h. 48m. | | |
| | | 29.945. Ther. 58°. | | |
| Bar. below | - | - | 29.850. Do. 58°. | yds. |
| Do. above | - | - | | 26. |
| | | Measured height | - | 29.351 |
| | | By Dr. MASKELYNE | - | |
| | | | error + | 3.351 |
| | | By Dr. HUTTON | - | error + 3.313 |

From the near agreement of the measured and barometrical heights on the summit of Skiddaw, I had formed sanguine hopes that the barometer would prove a most exact determinator of altitudes, and almost supersede the necessity of having recourse to any other mode; but the subsequent observations lead me to fear that the state of the atmosphere has an effect which we cannot yet account for, and to which we cannot apply a correction. When the operation was discontinued on the evening of the 5th, the air was dry and clear; but on the morning of the 6th, the top of the mountain was clouded about 300 yards down, which might be the reason of the two observations differing by more than four yards.

But the object of this paper is not to surmise, or submit any hypothesis; but faithfully to state the result of operations carried on with all the exactness I was capable of. If what I have done be deemed worthy of any attention by the learned and distinguished Society of which you, Sir, are a member, I shall be most highly gratified, and amply compensated for the toil attending operations on high mountains.

THOMAS GREATOREX.

P. S. Dr. MASKELYNE's rules for determining the height of mountains by the barometer, are these:

1st. Take the difference of the tabular logarithms of the observed barometrical heights at the two stations, considering the four first figures (exclusive of the index) as whole numbers, and the remaining figures to the right as decimals.

2dly. Observe the difference of FAHRENHEIT's thermometer

at the two stations ; multiply this difference by $\frac{454}{1000}$, and add or subtract this product, according as the thermometer was highest at the upper or lower station, which will give an approximate height.

3dly. Take the mean of the two altitudes of the thermometer, and find the difference between this mean and 32° . Multiply the approximate height by this difference, and the product by the decimal fraction .00244. This last correction being added to, or subtracted from the approximate height, according as the mean of the two altitudes of FAHRENHEIT'S thermometer was greater or less than 32° , will give the true height of the upper station in English fathoms.

Dr. HUTTON'S rules.

1st. Let the heights of the barometer at the top and bottom of any elevation intended to be measured, be observed as near the same time as may be, as also the temperatures of the attached thermometers, and also the temperature of the air in the shade at both stations, by means of detached thermometers.

2dly. Reduce these altitudes of the barometer to the same temperature by augmenting the height of the mercury in the colder temperature, or diminishing that in the warmer by its $\frac{1}{9600}$ part for every degree of difference of the two.

3dly. Take the difference of the common logarithms of the two heights of the barometer (so corrected), considering the four first figures (exclusive of the index) as whole numbers, and the rest to the right as decimals, which will give an approximate height.

4thly. Take the mean of the two detached thermometers ; and for every degree which this differs from 31° , take so many times the $\frac{1}{435}$ part of the approximate height ; and *add* them if the mean temperature be *above* 31° ; but *subtract* them if it be *below* 31° ; and the sum or difference will be the true altitude in fathoms.